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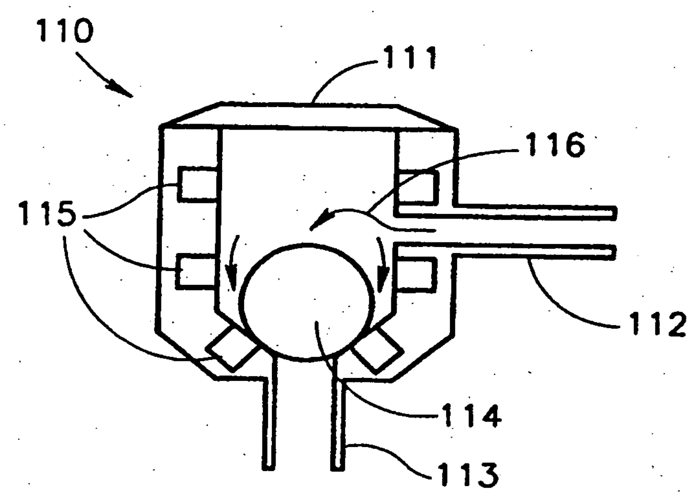
(54) Title: FLUID FLOW CONTROL SYSTEM

(57) Abstract

This invention is a fluid flow control system (10) which includes one or more electromagnetic devices (115) to control fluid flow such as valves (110), controllers, a control device to selectively activate the electromagnetic devices (115) according to predetermined conditions in one or more preselected external parameters, and means to measure the one or more preselected external parameters.



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FLUID FLOW CONTROL SYSTEM

FIELD OF THE INVENTION

The present invention relates to automatically controlled fluid flow systems.

BACKGROUND OF THE INVENTION

There exist many devices and methods for controlling fluid flows. Areas in which such devices and methods find use include medical, industrial, automotive, aeronautical, sewage treatment and water management, among many others.

Many of these areas require very precise control of small quantities of fluid. Such areas include medical infusion systems and pharmaceutical or chemical production. In many of these areas, complex mechanical or electromechanical solutions exist, although attempts have been made to find electromagnetic solutions. In addition to quantitative control of fluid flow, there is also a need to control fluid flow at precise times or in response to specific predetermined conditions.

United States Patent No. 5,002,055 discloses an apparatus for biofeedback control of body functions, by monitoring these functions and administering medication automatically if predetermined parameter measurements yield results outside predetermined limits. The apparatus disclosed activates and deactivates pumps on to control the administration of medication, with limited capability of precise control of the flow thereof. It further can only be produced as a total, integrated, system not readily adaptable to existing infusion or medication administration apparatus.

SUMMARY OF THE INVENTION

The present invention seeks to provide a multi-purpose fluid flow control system wherein the flow of preselected fluids is regulated in real-time by measurement of preselected parameters, according to predetermined conditions. The present invention is further capable of providing very high resolution regulation of fluid flows with very fast response to variations in the preselected parameter measurements. The present invention is further capable of being employed with an existing fluid flow control system, such as a suitable medical infusion system, as an alternative to being a fully self-contained system.

There is thus provided, in accordance with a preferred embodiment of the invention, a fluid flow control system which includes one or more electromagnetic devices to control fluid flow such as valves and controllers, a control device to selectively activate the electromagnetic devices according to predetermined conditions in one or more preselected external parameters, and means to measure the one or more preselected external parameters.

In accordance with a preferred embodiment of the present invention, the electromagnetic fluid flow control valve includes a fluid flow conduit with one or more fluid inlets and one or more fluid outlets, and with one or more discrete magnetic elements located within the conduit that are positioned by means of a number of selectably activated electromagnets located in association with the conduit. The magnetic element or elements can preferably be positioned either to close fluid flow by engaging a predetermined fluid inlet or outlet thereby to block fluid flow therethrough or to open fluid flow by not blocking fluid flow therethrough.

In accordance with additional embodiments of the present invention, the magnetic element or elements can further be selectably positioned in an intermediate position between the abovementioned open and closed positions thereby selectably to partially block fluid flow in the conduit thereby to provide precise control of the fluid flow therethrough.

Further, in accordance with a preferred embodiment of the present invention, the magnetic element or elements comprise a core of magnetic material covered with a material operative to engage a fluid inlet or outlet thereby to form a fluid-tight seal.

In accordance with additional embodiments of the present invention, a plurality of magnetic elements are located within a fluid flow conduit and are prevented from being driven downstream in the conduit by fluid flow therein by screen elements positioned at fluid outlets. In alternative embodiments of the present invention, the arrangement and size of the screen element holes provide a capability of engaging individual magnetic elements to totally block fluid flow when the magnetic elements are in the closed position.

Further, in accordance with a preferred embodiment of the present invention, the electromagnetic fluid flow controller includes a fluid flow conduit, a magnetic membrane, and a plurality of discrete sources of selectably variable magnetic fields, such as electromagnets, arranged in an ordered array, to drive the membrane in a desired manner to control the flow of fluid in the conduit. The membrane can preferably be driven between two extreme positions wherein the flow of fluid in the conduit is totally unrestricted in the rest position of the membrane and wherein the flow is highly restricted or stopped completely in the maximum deformation of the membrane radially inward.

Further, in accordance with a preferred embodiment of the present invention, the electromagnetic flow control apparatus additionally includes a control device to selectively activate the array of electromagnets so to produce a desired deformation in the magnetic membrane and a desired time variation thereof.

In accordance with a preferred embodiment of the present invention, the flow control apparatus is an integrated fluid flow conduit and electromagnetic control apparatus wherein the magnetic membrane is the body of or is embedded in the fluid flow conduit. In accordance with an alternative embodiment of the present invention, the flow control apparatus encloses an existing fluid flow conduit and controls the fluid flow therein by exerting pressure thereon from without.

In accordance with additional embodiments of the present invention, the flow control apparatus additionally includes a rod member, which may be made of magnetic material, located centrally in the fluid flow conduit along the length of the flow control apparatus. Such a rod can enhance the capability of the flow control apparatus to cut off the flow of fluid in the conduit.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be more fully understood and appreciated from the following detailed description, taken in conjunction with the drawings, in which:

Fig. 1 is a block diagram of a fluid flow control system constructed and operative in accordance with a preferred embodiment of the present invention;

Fig. 2 is a block diagram of a medical fluid flow control system constructed and operative in accordance with a preferred embodiment of the present invention;

Figure 3A is a schematic illustration of a magnetically activated fluid flow control valve, constructed in accordance with a preferred embodiment of the present invention, in which a single flow regulating magnetic element is in a closed position to block fluid flow;

Figure 3B shows the valve of Figure 3A with the magnetic element in an open position;

Figure 3C shows the valve of Figure 3A with the magnetic element in an intermediate position;

Figure 4A is a schematic illustration of a magnetically activated fluid flow control valve, constructed in accordance with an alternative embodiment of the present invention, employing a plurality of magnetic elements which are in a closed position to maximally restrict or to block fluid flow;

Figure 4B shows the valve of Figure 4A with the magnetic elements in an open position to allow maximum fluid flow;

Figure 4C shows the valve of Figure 4A with the magnetic elements in intermediate positions to partially restrict fluid flow;

Figure 5 shows a typical cross-section of a magnetic element of an alternative embodiment of the present invention;

Figure 6 shows yet a further alternative embodiment of the present invention having one fluid inlet, two fluid outlets, and two magnetic elements.

Figure 7 shows yet a further alternative embodiment of the present invention having two fluid inlets, two magnetic elements, and one fluid outlet.

Figure 8 shows yet a further alternative embodiment of the present invention having one fluid inlet, one fluid outlet, and one magnetic element with a range of possible intermediate positions.

Figure 9A shows yet a further alternative embodiment of the present invention having a magnetic element that is a narrow spring.

Figure 9B shows yet a further alternative embodiment of the present invention having a magnetic element that is a wide spring.

Figure 10 shows yet a further alternative embodiment of the present invention having a disk-shaped or cylindrical magnetic element that is mounted on a spring.

Figure 11 is a schematic cross-sectional view of flow controller, constructed in accordance with an alternative embodiment of the invention, in which a magnetic membrane is controlled via a single array of electromagnets, only;

Figure 12 is a schematic cross-sectional view of flow controller, constructed in accordance with a further alternative embodiment of the invention, in which a magnetic membrane is controlled via a pair of electromagnet arrays;

Figures 13A, 13B, and 13C are isometric, side-sectional, and cross-sectional views, respectively, of an integrated fluid flow conduit and electromagnetic flow controller, constructed in accordance with a further alternative embodiment of the invention;

Figures 14A and 14B are cross-sectional views of the conduit of Figures 13A, 13B and 13C, in partially closed and fully closed positions, respectively;

Figure 15A is a side-sectional view of a conduit and fluid controller, similar to that of Figures 13A-14B, but including a rod member extending longitudinally therein;

Figs. 15B and 15C are cross-sectional views of the conduit of Figure 15A, in fully open and fully closed positions, respectively;

Figure 16A is a side-sectional view of a fluid controller, according to another embodiment of the invention, for use with an existing fluid flow conduit, also shown in the figure; and

Figure 16B is a side-sectional view of a fluid controller similar to that in Figure 11A, with the addition of a protective air cushion around the existing fluid flow conduit.

Figure 17 is a block diagram of a controller circuit forming part of the controller shown in Figure 11.

Figure 18 is a block diagram of a driver circuit forming part of the controller shown in Figure 11.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to Figure 1, there is shown, a block diagram of a fluid flow control system, referred to generally as 10, in accordance with a preferred embodiment of the present invention. A subject system 11 requires controlled administration of a preselected number of fluids S1...Sn, each stored in its own reservoir 18, wherein each reservoir has either a valve 16 or controller 17 that is magnetically controlled to regulate the fluid flow from the reservoirs 18 into the subject system 11. The flow of all the fluids Sn is controlled by a computer 12 which, via signal converter 13, reads a preselected number of sensors SNS1...SNSn 14, which measure predetermined parameters of the subject system 11 or its environment 19. Specifically, the computer 12 has preprogrammed criteria for operating magnetic controller 15 to activate the valves 16 and controllers 17 that regulate the fluid flow, based on the parameter readings of the sensors SNSn 14.

Referring now to Figure 2, there is shown, a block diagram of a medical fluid flow control system, referred to generally as 20, in accordance with an additional preferred embodiment of the present invention. A patient 21 requires controlled administration via infusion apparatus (IV) 28 of a preselected number of medical fluids, such as saline solution 41, glucose solution 42, or a preselected number of medicaments

MED1...MEDn 43, each stored in its own reservoir, wherein each reservoir has either a valve 26 or controller 27 that is magnetically controlled to regulate the fluid flow from the reservoirs 41, 42, 43 to the infusion apparatus (IV) 28. The flow of all the fluids is controlled by a computer 22 which, via signal converter 23, reads a preselected number of sensors 31, 32, 33, 34, which measure predetermined bodily functions of the patient 21, such as blood pressure 32 or EKG 33 or the patient's environment 29, such as the room temperature 31. Specifically, the computer 22 has preprogrammed criteria for operating magnetic controller 25 to activate the valves 26 and controllers 27 that regulate the fluid flow into infusion system (IV) 28, based on the parameter readings of the sensors 31, 32, 32, 34. The requisite data acquisition and analysis functions can be performed by commercially available systems such as the VI-MASTERLAB™ system distributed by Lafayette Instrument Company, 3700 Sagamore Pkwy. N.; Lafayette, IN 47904, USA.

In both of the preferred embodiments of the present invention described above, the fluid flow control and medical infusion systems include a number of magnetically activated valves (16 and 26) and controllers (17 and 27) to regulate the flows of the individual preselected fluids. These magnetically activated devices provide the flow control and medical infusion systems with particularly high resolution control of the fluid flows and quick response to the directives of the controlling computers (12 and 22). As will be understood by persons skilled in the art, these qualities are highly desirable in a fluid flow control or medical infusion system.

A further advantage of these magnetically activated devices, as will be understood by persons skilled in the art and as will become apparent from the description of the devices to follow, is that they can be readily installed in an existing fluid flow control or medical infusion system.

The embodiments of the magnetically-activated fluid flow control valve are shown in Figures 3 through 10, described in detail below; and the embodiments of the magnetically-activated flow controller are shown in Figures 11 through 18.

Referring now to Figures 3A, 3B, and 3C, there is shown, schematically, a fluid flow control valve, referred to generally as 110, constructed in accordance with a preferred embodiment of the present invention. A fluid flow conduit 111 having a fluid inlet 112 and a fluid outlet 113 has a ball-shaped magnet element 114 totally contained within the conduit and which can be selectably positioned within the conduit by selectively activating electromagnets 115, mounted in association with the conduit 111, typically as shown in Figure 3A. As shown in Figure 3A, the ball-shaped magnetic element 114 can be positioned in engagement with the fluid outlet 113 of the conduit, thereby blocking fluid flow 116 therethrough. As shown in Figure 3B, the ball-shaped magnetic element 114 can alternatively be positioned with respect to the fluid outlet 113 of the conduit so as to leave fluid flow 116 therethrough substantially unhindered. So configured, such an embodiment of the present invention serves as a shutoff valve for fluid flow. In accordance with a further preferred embodiment of the invention, the ball-shaped magnetic element 114 can be positioned within the conduit 111 so as to partially restrict or to regulate fluid flow 116 therethrough, as shown in Figure 3C. With suitable positioning of the electromagnets 115 and with fine control of the magnetic fields 117 they generate, fine control of the rate of fluid flow 116 through the conduit 111 can be achieved.

Referring now to Figures 4A, 4B, and 4C, there is shown, schematically, a fluid flow control valve, referred to generally as 120, constructed in accordance with a alternative embodiment of the present invention. A fluid flow conduit 121 having one fluid inlet 122 and one fluid outlet 123 has a plurality of discrete magnet elements 124 totally contained within the conduit and a screen element 128 located over the fluid outlet 123. The screen element 128 prevents magnetic elements 124 from leaving the conduit 121 with the fluid flow 126. The magnetic elements can be selectably positioned within the conduit by selectively activating electromagnets 125, mounted in association with the conduit 121, typically as shown in Figure 4A. As shown in Figure 4A, the magnetic elements 124 can be positioned in engagement with the screen element 128 of the fluid outlet 123 of the conduit 121, thereby blocking or nearly blocking, depending

on the distribution and size of openings for fluid flow in the screen 128, fluid flow 126 therethrough. As shown in Figure 4B, the magnetic elements 124 can be positioned with respect to the fluid outlet 123 of the conduit 121 so as to leave fluid flow 126 therethrough totally unhindered. So configured, such an embodiment of the current invention serves as a shutoff valve for fluid flow. In accordance with a further embodiment of the invention, the magnetic elements 124 can be positioned within the conduit 121 so as to partially restrict fluid flow 126 therethrough, as shown in Figure 3C. With suitable positioning of the electromagnets 125 and with fine control of the magnetic fields 127 they generate, fine control or regulation of the rate of fluid flow 126 through the conduit 121 can be achieved.

The magnetic elements 114 and 124 in Figures 3 and 4 respectively may be fabricated entirely of magnetic material or, in alternative embodiments of the present invention, they can be comprised of a core of magnetic material 131, which can optionally be a permanent magnet, with an outer coating 132, as shown in Figure 5. The outer coating is preferably of a material operative to engage either a predetermined fluid inlet or outlet or any of the openings for fluid flow in screen element 128 so as to provide a fluid-tight seal with that predetermined fluid inlet or outlet or opening in screen element 128.

As will be understood by persons skilled in the art, fluid flow control valves are used to mix or select fluids coming from a number of inlets and route their flow via selected outlets. Referring now to Figures 6 and 7, there are shown, in alternative embodiments of the present invention, a fluid flow control valve having one fluid inlet 642, two fluid outlets 642 and 643, and two magnetic elements 644 and a fluid flow control valve having two fluid inlets 646 and 647, two magnetic elements 644' and 644" respectively, and one fluid outlet 648. It will be further appreciated by persons skilled in the art, that the configurations of fluid inlets and outlets in Figures 6 and 7 are shown merely by way of example, and that the scope of the present invention is not by limited thereby. In Figure 6, by selective positioning of magnetic elements 644, fluid flow from the fluid inlet 641 is selectably stopped or routed via a specific fluid outlet, 642 or 643,

or the combination thereof. In Figure 7, by selective positioning of magnetic elements 644' and 644", fluid flow is selected from a desired fluid inlet 646 or 647, respectively, or the combination thereof, and is routed via fluid outlet 648. In the example shown in Figure 7, the right magnetic element 644" is positioned to stop fluid flow from the right fluid inlet 647, and the left magnetic element 644' is positioned to permit fluid flow from the left fluid inlet 646.

Referring now to Figure 8, there is shown, schematically, a fluid flow control valve, referred to generally as 60, constructed in accordance with an alternative embodiment of the present invention. A fluid flow conduit 61 having a fluid inlet 62 and a fluid outlet 63 has a single ball-shaped magnet element 64 totally contained within the conduit and a plurality of electromagnets 65, mounted in association with the conduit 61. By selectively activating the electromagnets 65, the magnetic element 64 can be positioned selectably within the conduit 61 so as to provide high resolution control of the fluid flow therethrough.

In accordance with further embodiments of the invention, there are shown, in Figures 9A and 9B, fluid flow control valves 70 wherein the magnetic element 74 in the conduit 71 is spring-shaped, optionally fitted with disk-shaped elements 78 on each end, as shown in the figures. The spring-shaped magnetic elements 74 may be narrow, as shown in Figure 9A, or wide, as shown in Figure 9B, to provide an additional measure of control over the fluid flow through the conduit 71. The wide magnetic element 74 in Figure 9B can further be positioned so as to block fluid flow completely. The optional disks 78 can block the fluid flow completely by engaging the fluid inlet 72 or outlet 73.

Referring now to Figure 10, there is shown, schematically, a fluid flow control valve, referred to generally as 80, constructed in accordance with a further alternative embodiment of the present invention. In the present embodiment, a cylindrical disk-shaped magnetic element 84 is mounted on a spring 89 which serves to provide a positioning force for the element 84 in addition to that provided by electromagnets 84. As shown in the figure, the cylindrical disk-shaped element 84 can be positioned to block fluid flow from a selected inlet 83' to the conduit 81 or partially block, thereby to

control, the flow through a second inlet 82 and outlet 83 to the conduit 81. In a variation of the present embodiment, not shown, the cylindrical disk-shaped magnetic element 84 is replaced by a number of cylindrical disk-shaped magnetic elements mounted and positioned so as to selectably block fluid flow from a selected number of inlets or outlets.

Referring, now to Figure 11, there is shown, schematically, a fluid flow controller, referred to generally as 210, in accordance with a further embodiment of the present invention. A magnetic membrane 211 is located opposite an array of electromagnets 212. The array may be linear, as in Figure 11, or planar. Electric power from the power supply 214 is distributed among the electromagnets of the array 212 by a controller and driver unit 213 so as to create varying magnetic fields 215 which produce a desired wavelike, dynamic, deformation of the membrane 211'. When the membrane is placed within or adjacent to a fluid flow conduit with fluid flowing therein, as shown by arrows 216, the deformation will cause a corresponding variation in the fluid flow characteristic. The use of a plurality of electromagnets 212 and the electronic control thereof to produce electromagnetic fields 215 acting on the membrane element 211 which directly affects the fluid flow, provides high resolution and real time control thereof.

Figures 17 and 18 show block diagrams of examples of controller and driver circuits, respectively, which together may constitute controller and driver unit 13 shown in Figure 11. These circuits, as will be understood by persons skilled in the art, are operative to distribute power to the the electromagnets of the array to create the aforementioned varying magnetic fields.

As will be understood by persons skilled in the art, magnetic membranes 211 can have a number of alternative configurations. These may be, in alternative embodiments of the invention, by way of example, any of the following:

- a single membrane made of a flexible magnetic material, such as polyethylene impregnated with iron filings or with nickel

- a compound membrane having joined magnetic and non-magnetic layers wherein the magnetic layer transfers forces resulting from its deformation as described above to the non-magnetic layer
- a single non-magnetic membrane having magnetic elements embedded therein
- a single non-magnetic membrane having magnetic elements attached to its surface

It will be further understood by persons skilled in the art that such magnetic elements may be permanent magnets or other magnetic material.

In an additional embodiment of the present invention, shown schematically in Figure 12, a second array of electromagnets 227, similar to the first array 222, is located opposite the magnetic membrane 221. The use of an additional array provides enhanced spatial and temporal response in the magnetic membrane 221 with resulting enhanced control of the flow of the fluid in the conduit.

As will be understood by persons skilled in the art, the more discrete locations whereat electromagnetic fields can be applied to the magnetic membrane, the greater is the resolution of the control over the deformation thereof.

Referring now to Figures 13A, 13B, and 13C, there is shown, in isometric, side-sectional, and cross-sectional views, respectively, an integrated fluid flow conduit and electromagnetic flow control apparatus, constructed in accordance with a preferred embodiment of the present invention. In this embodiment, a plurality of arrays of electromagnets 232 are arranged cylindrically around a fluid flow conduit 231 whose walls are made of magnetic material. Figure 13C shows the cross-sectional view of the conduit 231 when it is fully open. Figures 14A and 14B, show the conduit 231 when it is partially closed and fully closed, respectively, as a result of the application of suitable magnetic fields via the arrays of electromagnets.

The spatial resolution of the control of the deformation of the fluid flow conduit, together with the time resolution of the control provided by electronic control of the individual electromagnets allows such embodiments of the present invention to impart a wavelike motion to fluid flows along the conduit 231 along its length, as indicated by

211' and 221' in Figures 11 and 12 respectively, so as to drive the flow fluid though the conduit in a peristaltic-like fashion.

Referring now to Figures 15A, 15B, and 15C, there is shown an alternative embodiment of the present invention wherein an integrated fluid flow conduit and electromagnetic flow control apparatus additionally includes a rod 253 running longitudinally in the center of the fluid flow conduit 251. Rod 253 is supported by any suitable mounting elements (not shown). When the magnetic elements 252 are activated to close the fluid flow conduit 251, as shown in Figure 15C, the magnetic membrane wall of the conduit 251 presses against the rod 253, thereby providing a firmer seal to close the conduit to fluid flow. In accordance with a further embodiment of the present invention, the rod 253 may be made of magnetic material in order to enhance the magnetic force for closing the fluid flow in the conduit 251.

In a further preferred embodiment of the present invention, an electromagnetic flow controller 262 is employed in conjunction with an existing fluid flow conduit 261, as shown in Figures 16A and 16B. In this embodiment of the invention, an electromagnetic flow control apparatus 262, including a magnetic membrane 263, is a sleeve-like construction that is placed around a segment of an existing fluid flow conduit 261. The deformation of the magnetic membrane 263 in response to the magnetic fields produced by the apparatus 262 presses on the conduit to control the fluid flow therein. In alternative embodiment of the invention, the electromagnetic flow control apparatus 262 may include a gas-filled cell 265 separating the magnetic membrane 263 from the fluid flow conduit 261 to provide a cushion to protect the conduit from excessive forces.

It will further be appreciated, by persons skilled in the art that the scope of the present invention is not limited by what has been specifically shown and described hereinabove, merely by way of example. Rather, the scope of the present invention is defined solely by the claims, which follow.

CLAIMS

1. For use with a fluid flow, a control system which comprises:

electromagnetic means for automatically controlling fluid flow,

means for operating said electromagnetic fluid flow control means in accordance with at least one predetermined parameter external to the system, and

means for sensing the at least one predetermined external parameter;

wherein said electromagnetic fluid flow control means comprises at least one of a device for regulating fluid flow and a flow control apparatus, wherein:

said device for regulating fluid flow comprises:

a conduit having at least one fluid inlet and at least one fluid outlet, associated with the fluid flow;

at least one discrete magnetic element located within said conduit; and

magnetic means for selectably positioning said at least one magnetic element with respect to said conduit, so as to provide regulation of the throughflow; and

said flow control apparatus comprises:

magnetic membrane means arranged in association with the fluid flow; and

means for selectably applying varying electromagnetic fields to said magnetic membrane means at a plurality of discrete locations therealong, thereby to drive said membrane means in a selected manner and thus to change the dynamic state of the fluid flow accordingly.

2. A control system according to claim 1 wherein said magnetic means of said device for regulating fluid flow is operative to selectably position at least one of said at least one magnetic element in at least a closed and an open position, wherein:

   in said closed position, said at least one magnetic element is located in engagement with a predetermined one of said fluid inlet and said fluid outlet thereby to block fluid flow therethrough, and

   in said open position, said at least one magnetic element is not located in engagement with either of said fluid inlet or said fluid outlet so as not to block fluid flow therethrough.

3. A control system according to claim 2 wherein said magnetic means is further operative to selectably position said at least one magnetic element in an intermediate position between said closed and open positions thereby to permit a selected fluid flow through said conduit.

4. A control system according to claim 3 wherein said magnetic means comprises a plurality of selectably actuable electromagnets distributed about said conduit so as to selectably exert magnetic forces on said at least one magnetic element so as to position said at least one magnetic element in a selected position within said conduit.

5. A control system according to claim 2 wherein each said at least one magnetic element comprises:

   a core of magnetic material; and

   an outer covering of material which is operative, when said at least one magnetic element is in said closed position, to engage one of said fluid inlet and said fluid outlet so as to form therewith a fluid-tight seal.

6. A control system according to claim 1 wherein said at least one magnetic element of said device for regulating fluid flow comprises a plurality of discrete elements.

7. A control system according to claim 5 additionally comprising at least one screen member in association with said at least one outlet for retaining said plurality of magnetic elements upstream of said outlet.

8. A control system according to claim 1, wherein said magnetic membrane means of said flow control apparatus comprises:

a non-magnetic layer; and

a magnetic layer arranged in force transfer association with said non-magnetic layer, wherein said magnetic layer is operative, in response to application thereto of electromagnetic fields, to drive said non-magnetic layer accordingly.

9. A control system according to claim 1, wherein said magnetic membrane means of said flow control apparatus comprises a non-magnetic membrane having magnetic elements arranged in fixed association therewith.

10. A control system according to claim 9, wherein said magnetic elements are implanted in said non-magnetic membrane.

11. A control system according to claim 9, wherein said magnetic elements are affixed to a surface of said non-magnetic membrane.

12. A control system according to claim 9, wherein said magnetic elements are permanent magnets.

13. A control system according to any of claims 1 and 8–12, wherein said means for applying electromagnetic fields of said flow control apparatus comprises means for applying varying electromagnetic fields to said magnetic membrane means generally perpendicular thereto.

14. A control system according to any of claims 1 and 8–13, wherein said means for applying electromagnetic fields of said flow control apparatus comprises means for moving said magnetic membrane means so as to impart thereto a predetermined wave motion.

15. A control system according to any of claims 1 and 8–14, wherein said magnetic membrane means of said flow control apparatus has a curved planar shape when at rest, and said means for applying electromagnetic fields comprises means for varying the degree of curvature of said magnetic membrane means.

16. A control system according to any of claims 1 and 8–15, wherein said means for applying electromagnetic fields of said flow control apparatus comprises:

a plurality of electromagnets arranged at discrete locations along said membrane means; and

control means for activating said electromagnets in a predetermined manner so as to move said magnetic membrane means in a corresponding manner.

17. A control system according to claim 16, wherein said magnetic membrane means is formed into a tube for carrying a fluid flow, said plurality of electromagnets are arranged at discrete locations along said tube and are further arranged radially thereabout, and

said control means is operative to activate said electromagnets in a predetermined manner so as to vary the cross-sectional configuration of said tube at predetermined locations therealong between predetermined first and second extreme positions,

wherein, when said tube is in said first extreme configuration, said plurality of electromagnets are not operated, and said tube is an a fully open, at rest position, thereby permitting flow therethrough,

and when said tube is in said second extreme position, said plurality of electromagnets are operated so as to force opposing wall portions of said tube radially inward, thereby to reduce the cross-sectional area of said tube so as to constrict fluid flow therealong.

18. A control system according to claim 17, and also including a rod located inside said tube and extending longitudinally therealong, wherein, when said tube is in said second extreme position, said wall portions of said at least a portion of said tube are pressed against said rod.

19. A control system according to claim 18, wherein said rod is magnetic.

20. A control system according to any of claims 1–19 wherein the at least one external parameter is a biological body value relating to a patient, and wherein the fluid flow is at least one preselected medical fluid for the patient, and wherein the control system is operative to control administration of the at least one preselected medical fluid to the patient.

21. A control system according to claim 20 wherein said control system comprises infusion control means.

22. A medical infusion system which comprises:

means for administering at least one selected medical fluid to a patient,

at least one reservoir arranged to contain a supply of the selected medical fluid, which is coupled to said means for administering the selected medical fluid,

a medical fluid flow,

a fluid flow control system which comprises:

electromagnetic means for automatically controlling fluid flow,

means for operating said electromagnetic fluid flow control means in accordance with at least one predetermined parameter external to the system, and

means for sensing the at least one predetermined external parameter;

wherein said electromagnetic fluid flow control means comprises at least one of a device for regulating fluid flow and a flow control apparatus, wherein:

said device for regulating fluid flow comprises:

a conduit having at least one fluid inlet and at least one fluid outlet, associated with the fluid flow;

at least one discrete magnetic element located within said conduit; and

magnetic means for selectably positioning said at least one magnetic element with respect to said conduit, so as to provide regulation of the throughflow; and

said flow control apparatus comprises:

magnetic membrane means arranged in association with the fluid flow; and

means for selectably applying varying electromagnetic fields to said magnetic membrane means at a plurality of discrete locations therealong, thereby to drive said membrane means in a selected manner and thus to change the dynamic state of the fluid flow accordingly.

23. A medical infusion system according to claim 22 wherein said magnetic means of said device for regulating fluid flow is operative to selectably position at least one of said at least one magnetic element in at least a closed and an open position, wherein:

in said closed position, said at least one magnetic element is located in engagement with a predetermined one of said fluid inlet and said fluid outlet thereby to block fluid flow therethrough, and

in said open position, said at least one magnetic element is not located in engagement with either of said fluid inlet or said fluid outlet so as not to block fluid flow therethrough.

24. A medical infusion system according to claim 23 wherein said magnetic means is further operative to selectably position said at least one magnetic element in an intermediate position between said closed and open positions thereby to permit a selected fluid flow through said conduit.

25. A medical infusion system according to claim 24 wherein said magnetic means comprises a plurality of selectably actuable electromagnets distributed about said conduit so as to selectably exert magnetic forces on said at least one magnetic element so as to position said at least one magnetic element in a selected position within said conduit.

26. A medical infusion system according to claim 23 wherein each said at least one magnetic element comprises:

a core of magnetic material; and

an outer covering of material which is operative, when said at least one magnetic element is in said closed position, to engage one of said fluid inlet and said fluid outlet so as to form therewith a fluid-tight seal.

27. A medical infusion system according to claim 22 wherein said at least one magnetic element of said device for regulating fluid flow comprises a plurality of discrete elements.

28. A medical infusion system according to claim 26 additionally comprising at least one screen member in association with said at least one outlet for retaining said plurality of magnetic elements upstream of said outlet.

29. A medical infusion system according to claim 22, wherein said magnetic membrane means of said flow control apparatus comprises:

a non-magnetic layer; and

a magnetic layer arranged in force transfer association with said non-magnetic layer, wherein said magnetic layer is operative, in response to application thereto of electromagnetic fields, to drive said non-magnetic layer accordingly.

30. A medical infusion system according to claim 22, wherein said magnetic membrane means of said flow control apparatus comprises a non-magnetic membrane having magnetic elements arranged in fixed association therewith.

31. A medical infusion system according to claim 30, wherein said magnetic elements are implanted in said non-magnetic membrane.

32. A medical infusion system according to claim 30, wherein said magnetic elements are affixed to a surface of said non-magnetic membrane.

33. A medical infusion system according to claim 30, wherein said magnetic elements are permanent magnets.

34. A medical infusion system according to any of claims 22 and 29–33, wherein said means for applying electromagnetic fields of said flow control apparatus comprises means for applying varying electromagnetic fields to said magnetic membrane means generally perpendicular thereto.

35. A medical infusion system according to any of claims 22 and 29–34, wherein said means for applying electromagnetic fields of said flow control apparatus comprises means for moving said magnetic membrane means so as to impart thereto a predetermined wave motion.

36. A medical infusion system according to any of claims 22 and 29–35, wherein said magnetic membrane means of said flow control apparatus has a curved planar shape when at rest, and said means for applying electromagnetic fields comprises means for varying the degree of curvature of said magnetic membrane means.

37. A medical infusion system according to any of claims 22 and 29–36, wherein said means for applying electromagnetic fields of said flow control apparatus comprises:

a plurality of electromagnets arranged at discrete locations along said membrane means; and

control means for activating said electromagnets in a predetermined manner so as to move said magnetic membrane means in a corresponding manner.

38. A medical infusion system according to claim 37, wherein said magnetic membrane means is formed into a tube for carrying a fluid flow, said plurality of electromagnets are arranged at discrete locations along said tube and are further arranged radially thereabout, and

said control means is operative to activate said electromagnets in a predetermined manner so as to vary the cross-sectional configuration of said tube at predetermined locations therealong between predetermined first and second extreme positions,

wherein, when said tube is in said first extreme configuration, said plurality of electromagnets are not operated, and said tube is an a fully open, at rest position, thereby permitting flow therethrough,

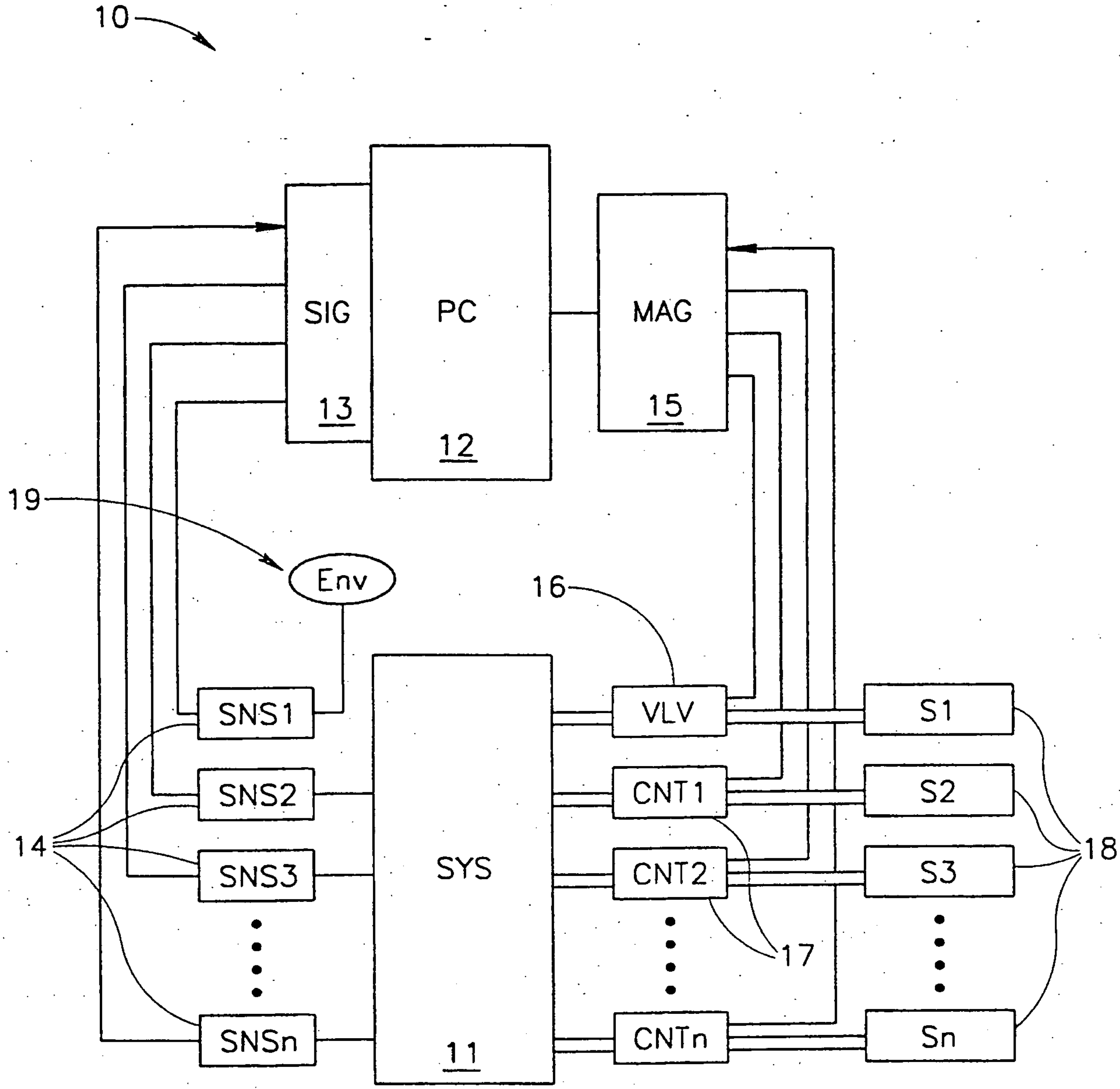
and when said tube is in said second extreme position, said plurality of electromagnets are operated so as to force opposing wall portions of said tube radially inward, thereby to reduce the cross-sectional area of said tube so as to constrict fluid flow therealong.

39. A medical infusion system according to claim 38, and also including a rod located inside said tube and extending longitudinally therealong, wherein, when said tube is in said second extreme position, said wall portions of said at least a portion of said tube are pressed against said rod.

40. A medical infusion system according to claim 39, wherein said rod is magnetic.

41. A medical infusion system according to any of claims 22–40 wherein the at least one external parameter is a biological body value relating to a patient, and wherein the fluid flow is at least one preselected medical fluid for the patient, and wherein the control system is operative to control administration of the at least one preselected medical fluid to the patient.

42. A medical infusion system according to claim 41 wherein said control system comprises infusion control means.



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S3
Sn
18

FIG.1

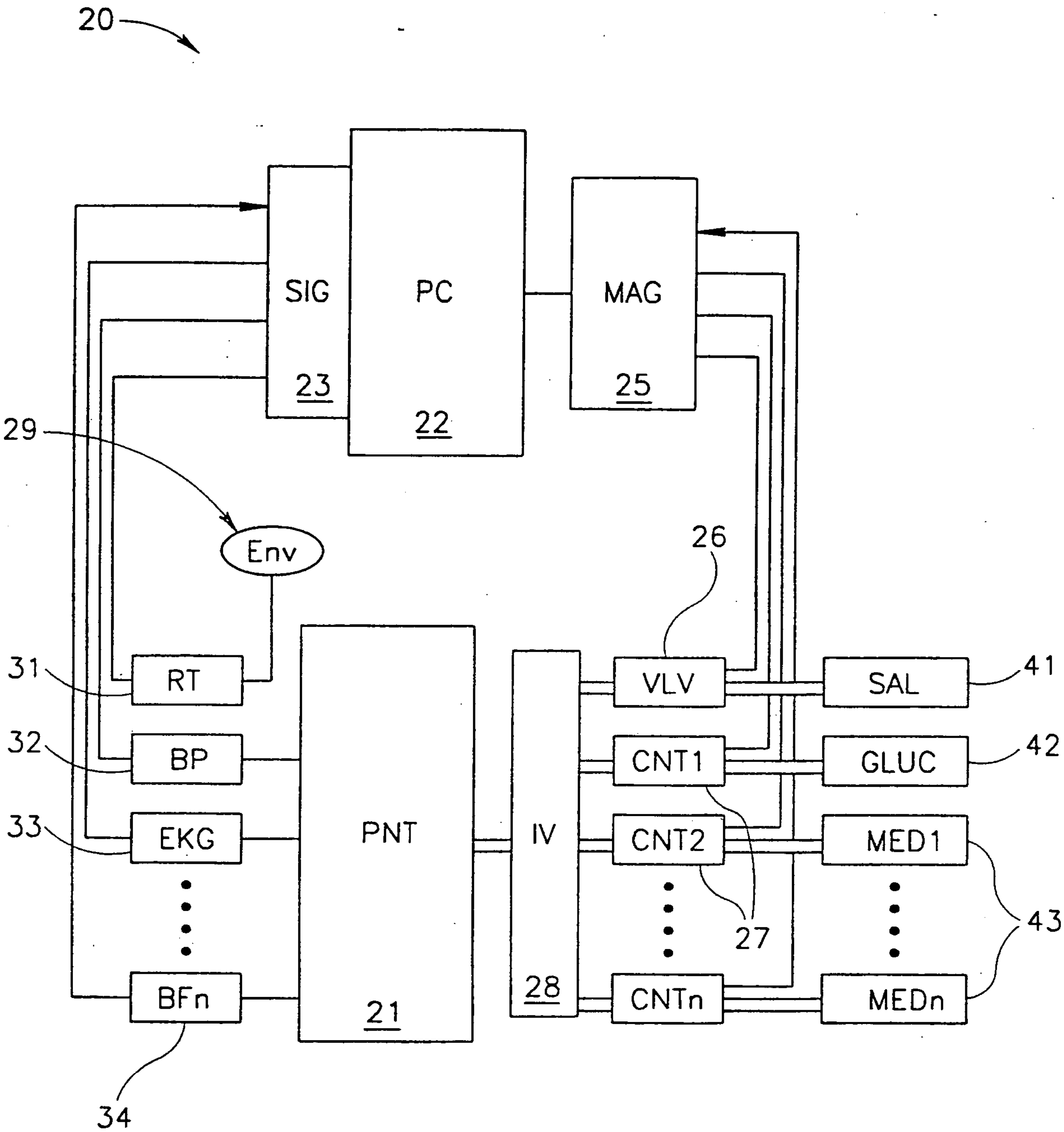

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FIG.2

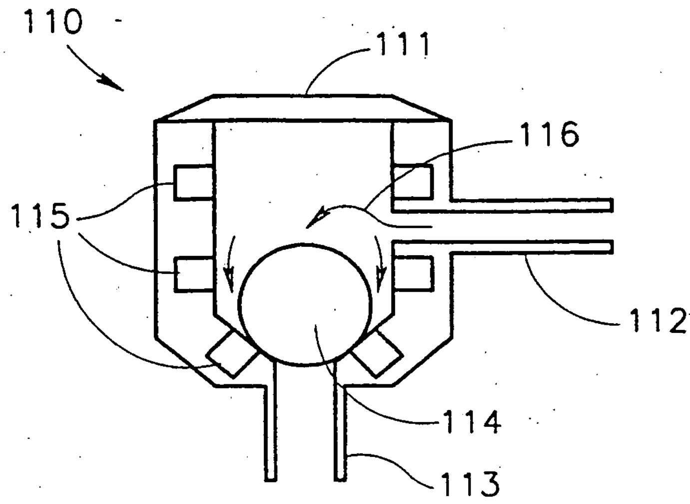


FIG.3A

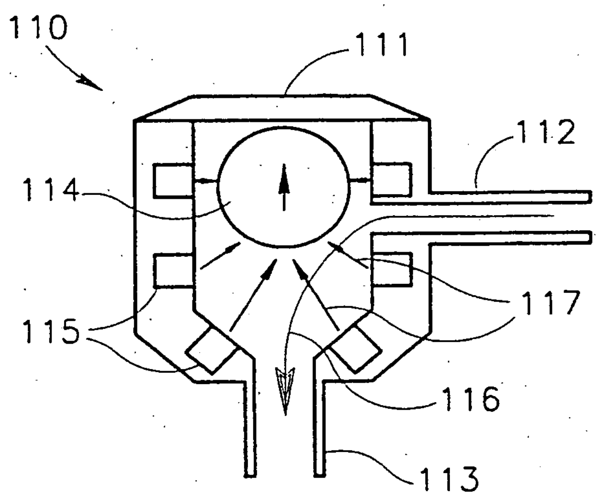


FIG.3B

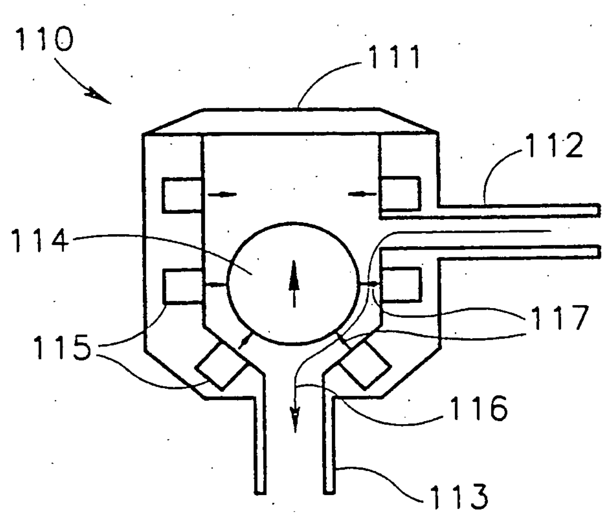


FIG.3C

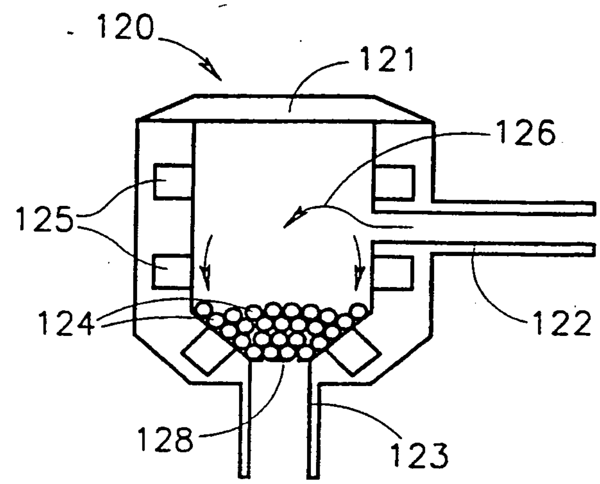


FIG.4A

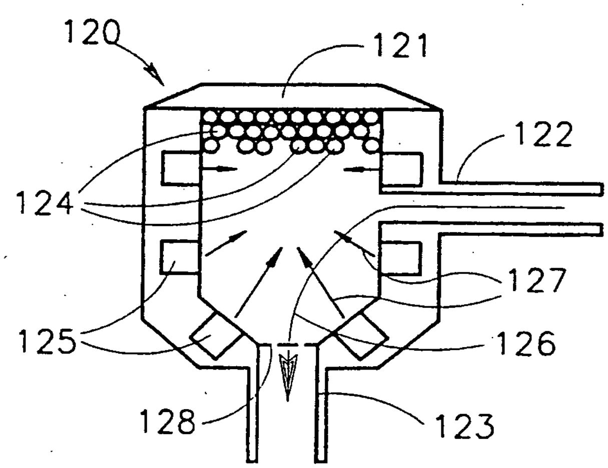


FIG.4B

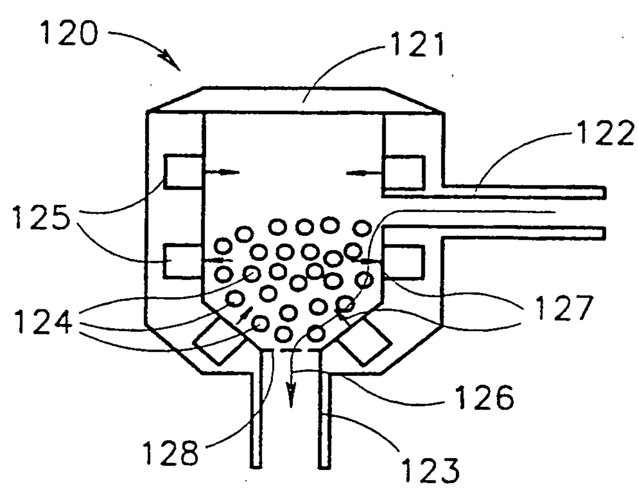


FIG.4C

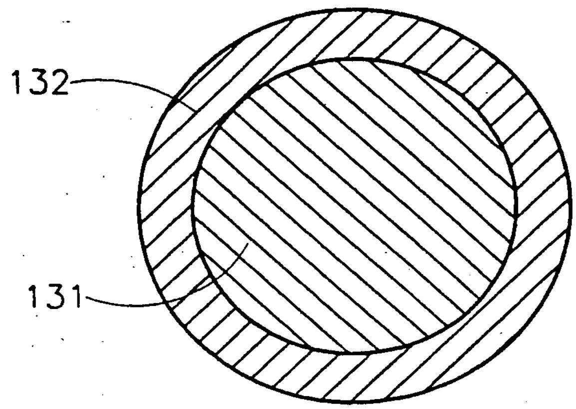


FIG.5

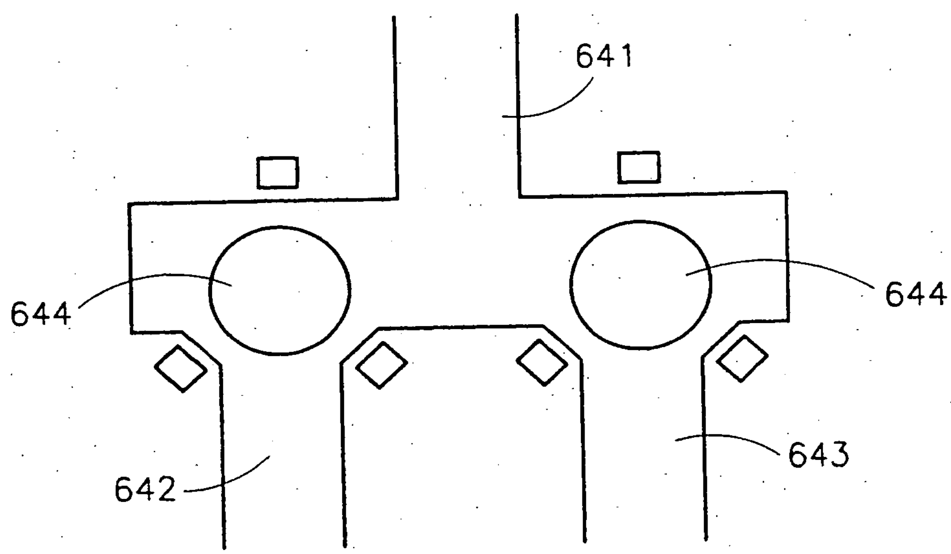


FIG.6

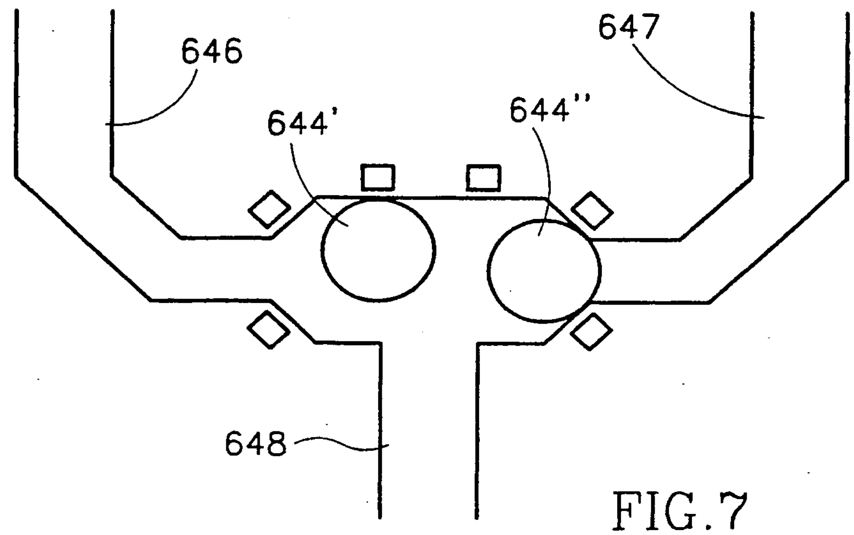


FIG.7

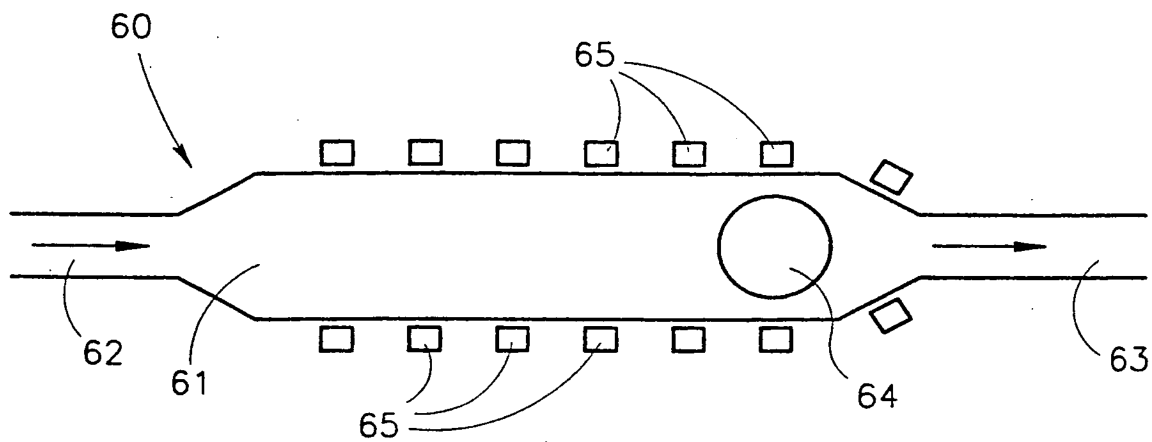


FIG.8

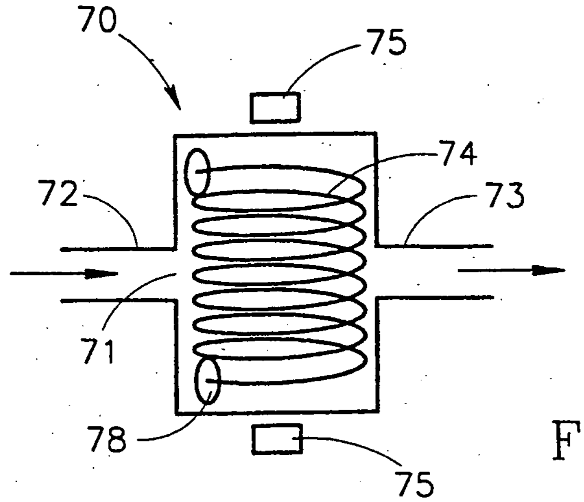


FIG.9A

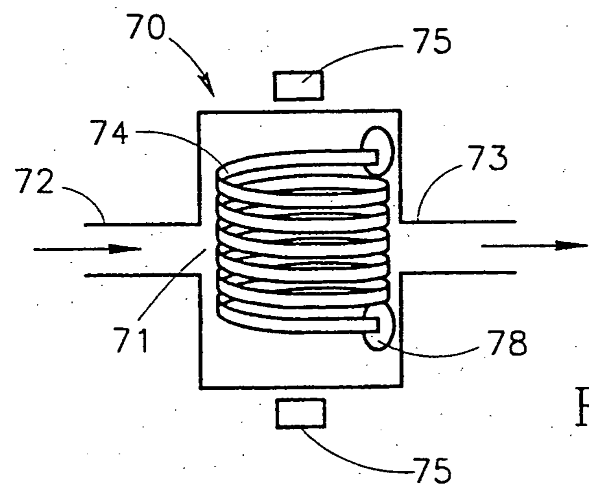


FIG.9B

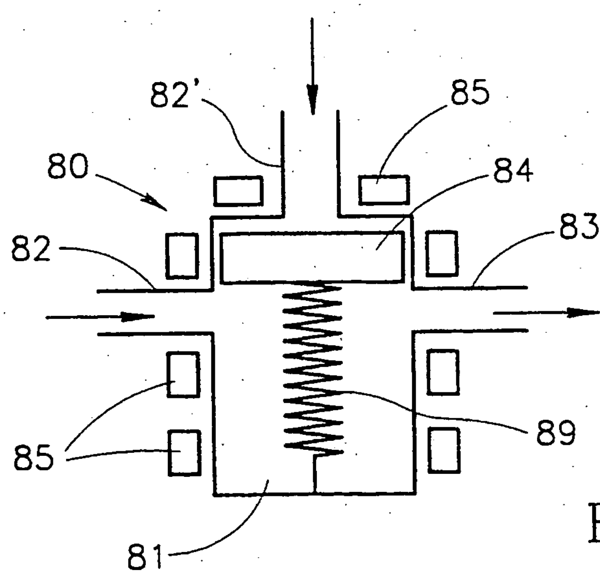
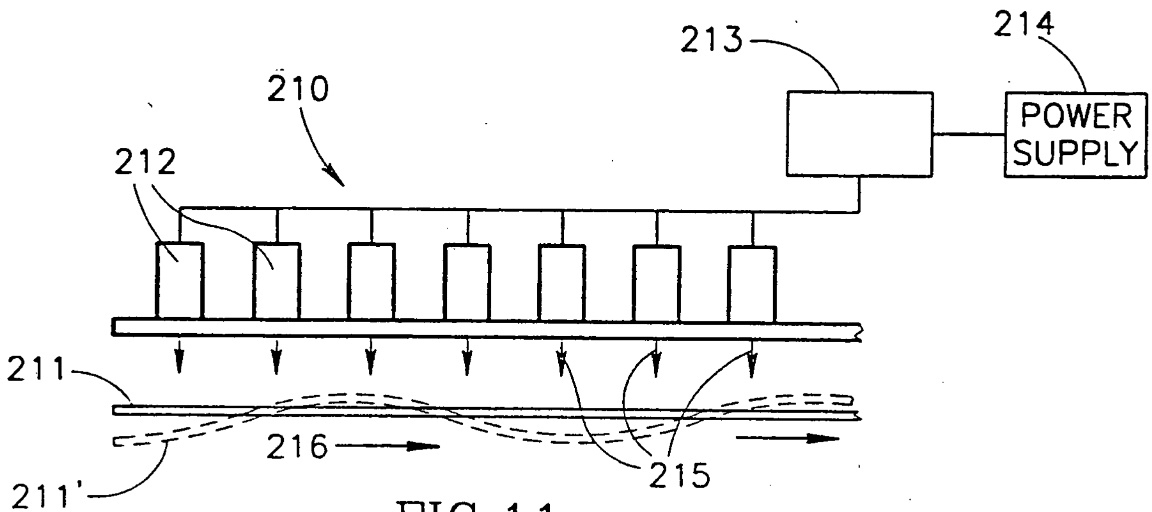


FIG.10



213
214
POWER SUPPLY
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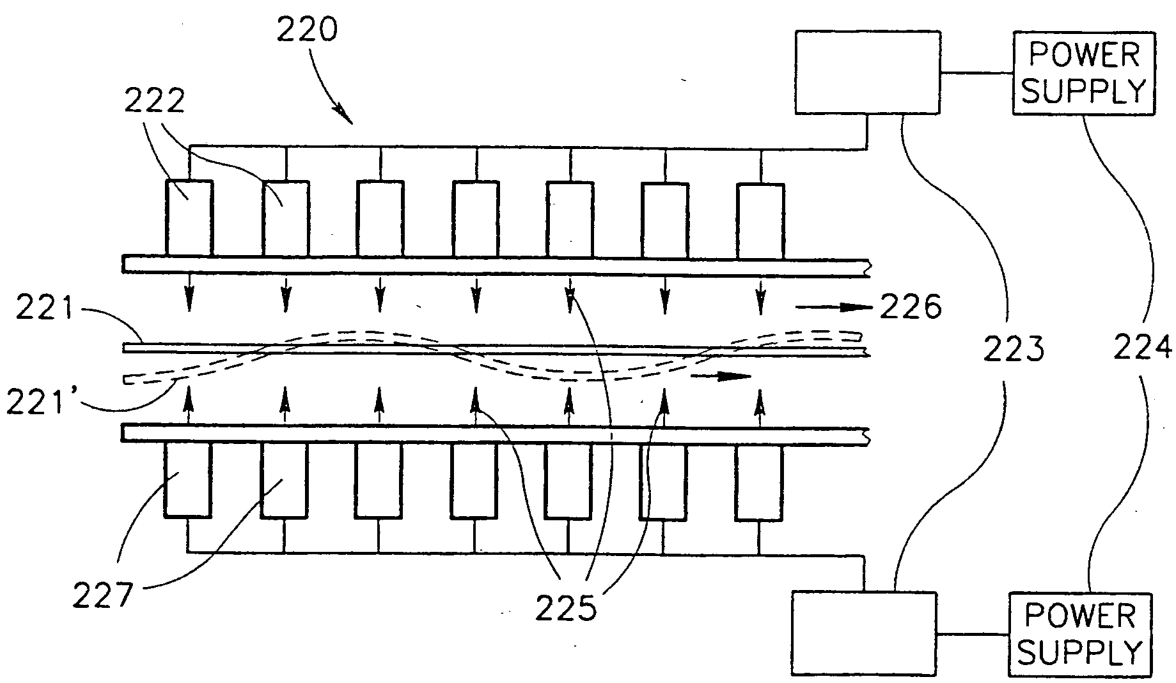
FIG.11



220
222
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221'
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POWER SUPPLY

FIG.12

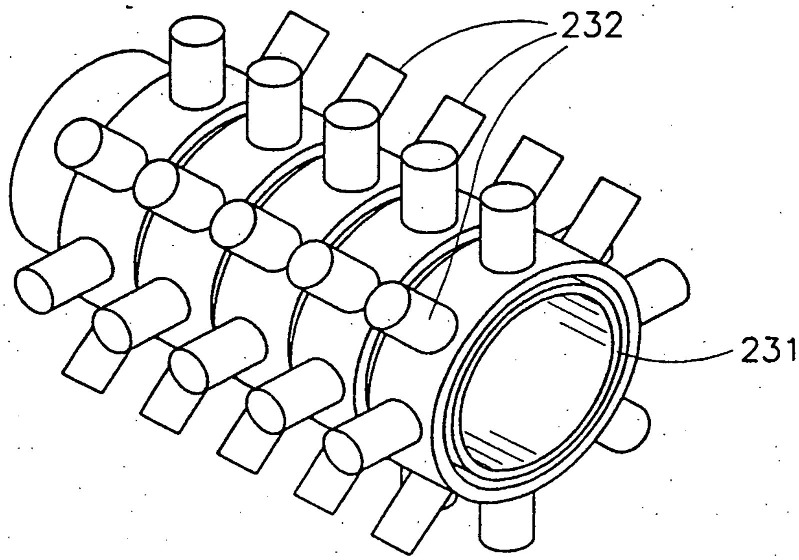


FIG.13A

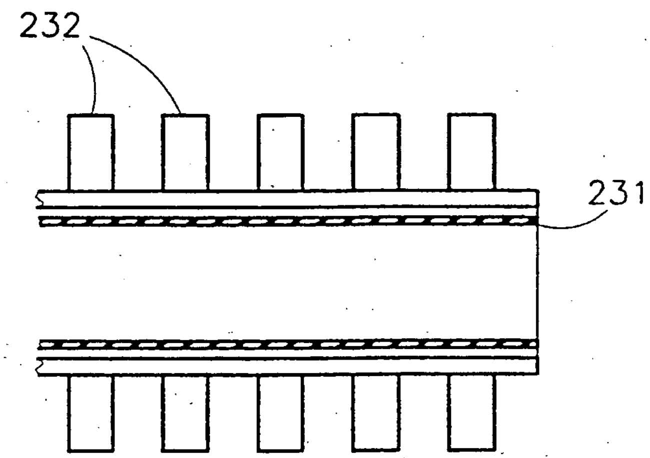


FIG.13B

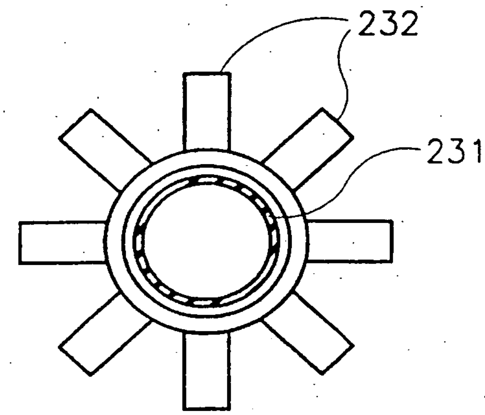


FIG.13C

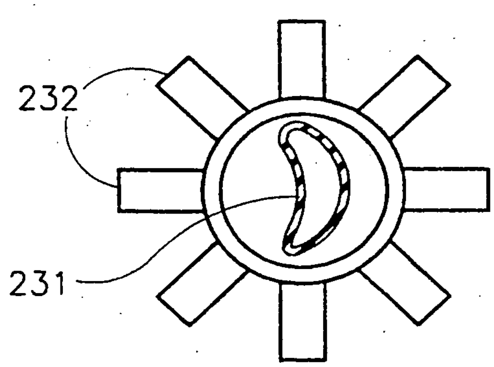


FIG.14A

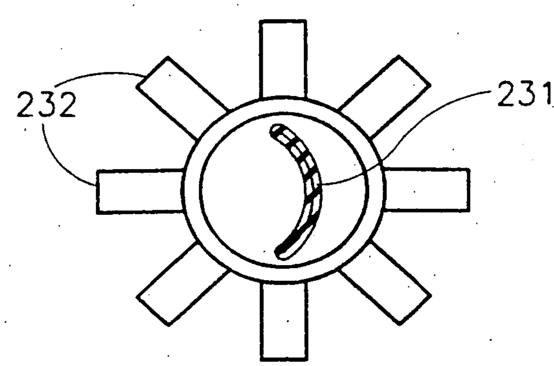


FIG.14B

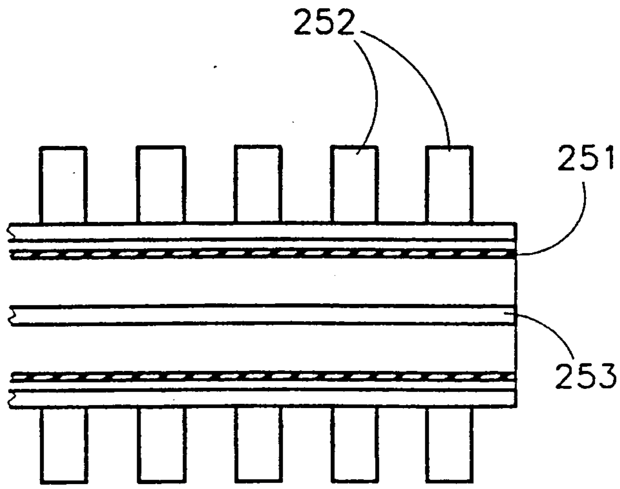


FIG.15A

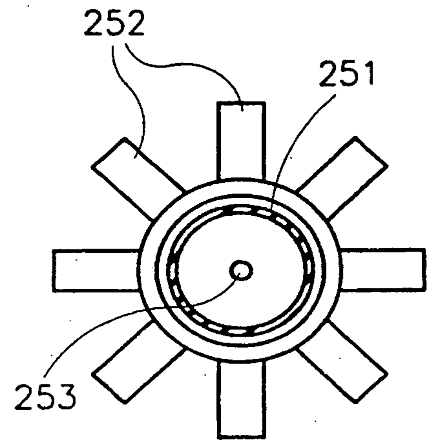


FIG.15B

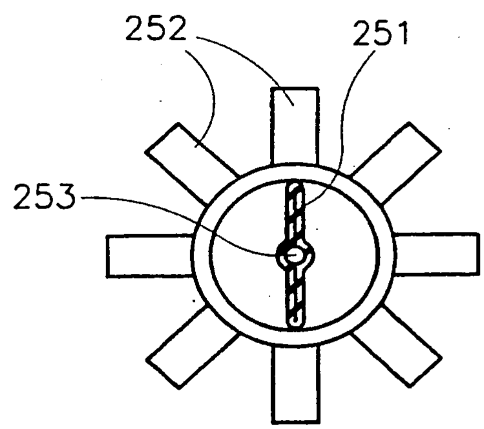


FIG.15C

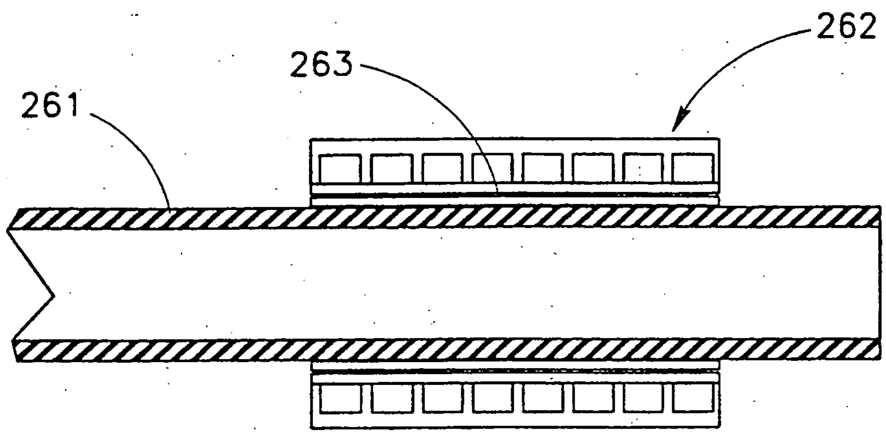


FIG.16A

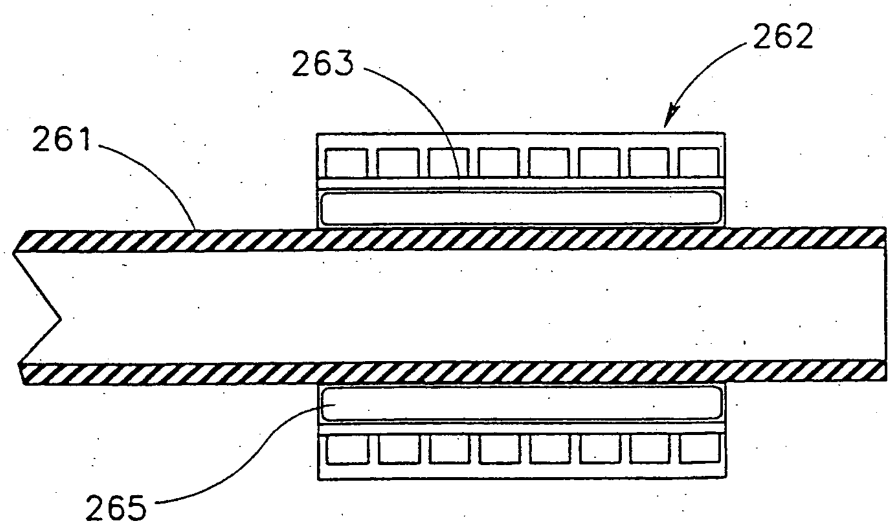
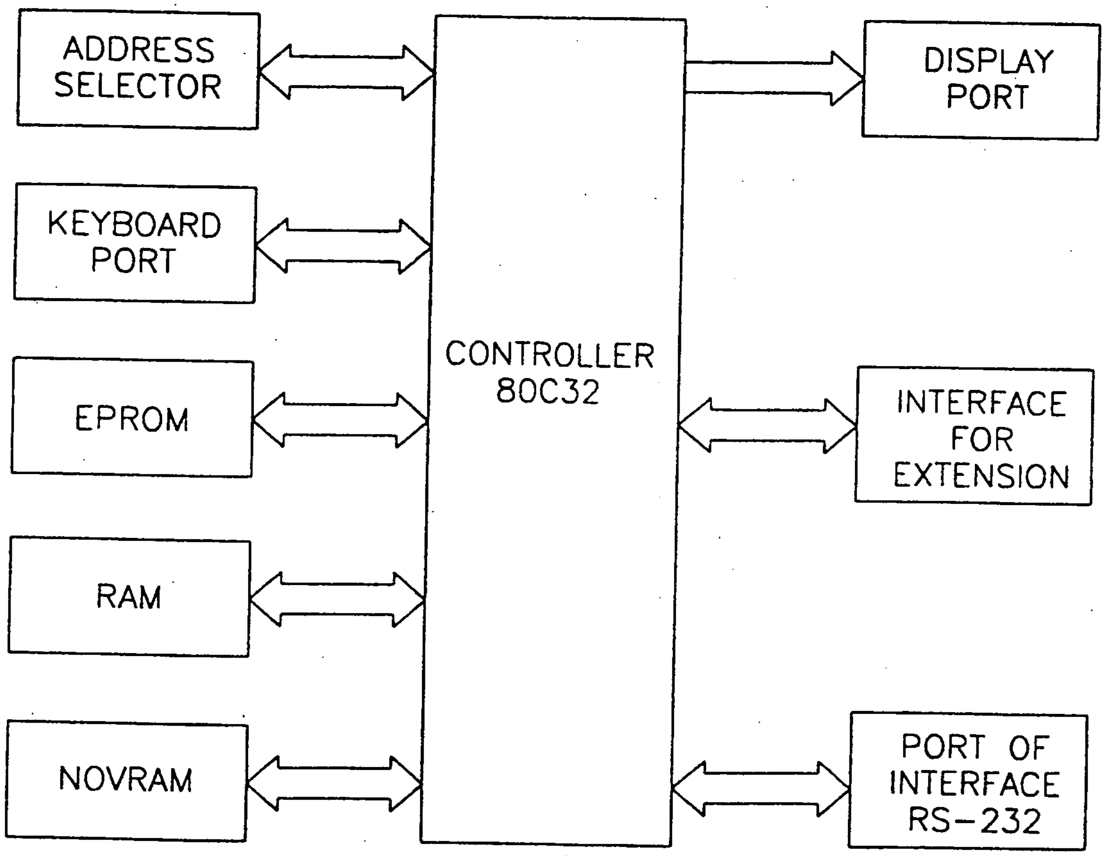


FIG.16B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EPROM
RAM
NOVRAM
CONTROLLER 80C32
DISPLAY PORT
INTERFACE FOR EXTENSION
PORT OF INTERFACE RS-232

FIG.17

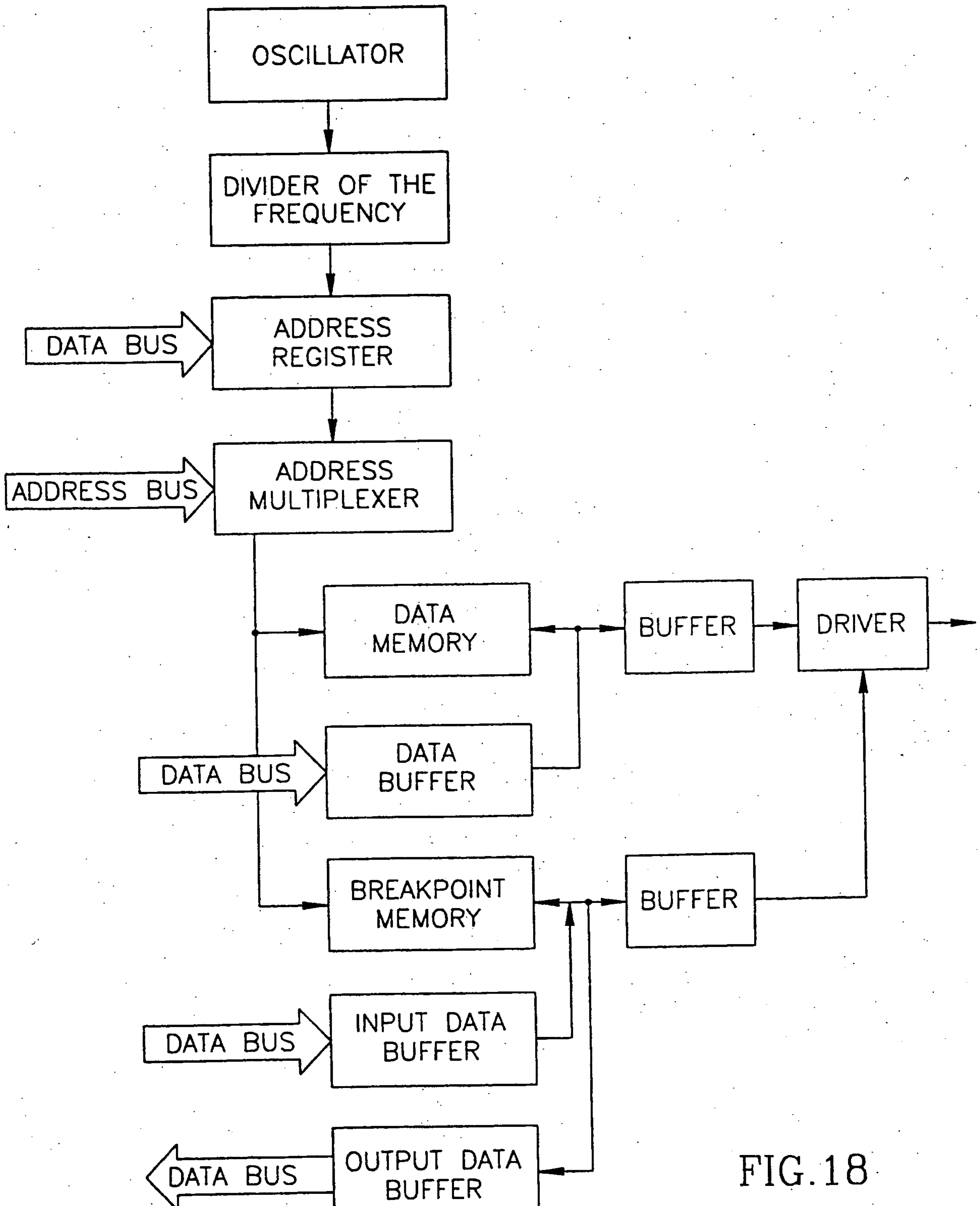
OSCILLATOR
DIVIDER OF THE FREQUENCY
DATA BUS
ADDRESS REGISTER
ADDRESS BUS
ADDRESS MULTIPLEXER
DATA MEMORY
BUFFER
DRIVER
DATA BUS
DATA BUFFER
BREAKPOINT MEMORY
BUFFER
DATA BUS
INPUT DATA BUFFER
DATA BUS
OUTPUT DATA BUFFER

FIG.18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL98/00128

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A61M 31/00
US CL :604/65

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 128/899; 604/65-67, 153, 246-249, 256, 890.1, 891.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 4,551,134 A (SLAVIK et al.) 05 November 1985, Figs. 2a and 2b, and related text.	1-3, 22-24 --- 5, 26
X --- Y	US 4,038,982 A (BURKE et al.) 02 August 1977, Figs. 4 and 5, and related text.	1-4, 22-25 --- 5, 26
X --- Y	US 3,890,968 A (PIERCE et al.) 24 June 1975, Figs. 1-8, and related text.	1-4, 22-25 --- 5, 26

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

10 JUNE 1998

Date of mailing of the international search report

16 JUL 1998

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Authorized officer
MICHAEL HAYES
Andre Robinson

Telephone No. (703) 305-5873

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,527,295 A (WING) 18 June 1996, Figs. 2 and 3, and related text.	5, 26
Y	US 5,302,093 A (OWENS et al.) 12 April 1994, Figs. 3, 8, 11, and 12, and related text.	1, 8-17, 22, 29-37
Y	US 5,582,593 A (HULTMAN) 10 December 1996, Figs. 6-11, and related text.	20-22, 41, 42